

Surface-insensitive retrievals

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Results for  
TMI

Adaptation to  
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Conclusions

# Surface-insensitive precipitation retrievals from GMI

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# Outline

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## 3 Adaptation to GMI

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# Objective

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## **Retrieve surface precipitation rates from multichannel microwave imagery.**

- radar-based observations as the benchmark and as the training data set;
- maximum instantaneous skill, including at low precipitation rates;
- minimum long-term RMS error and bias;
- all global surface types, including snow, ice, coast, desert;
- rigorous characterization of uncertainty. ←

# GMI Requirements

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- 1 “Quantify rain rates between 0.2 and 60 mm hr<sup>-1</sup> and demonstrated the detection of snowfall at an effective resolution of 15 km.”
- 2 “Instantaneous rain rate estimate with bias and random error <50% at 1 mm hr<sup>-1</sup> and <25% at 10 mm hr<sup>-1</sup> at 50 km resolution between Core Observatory and calibrated ground validation data.”

# Central Challenge for *Global* Retrievals

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Even in the absence of precipitation, passive microwave brightness temperatures vary sharply in both *time* and *space* due to variable surface emission and atmospheric properties:

- Coastlines and other water-land boundaries
- Vegetation and/or soil type
- Surface moisture
- Snow and ice cover
- Atmospheric water vapor and cloud water

**Successful global precipitation retrieval algorithms must be able ignore these variations yet still detect light precipitation rates.**

# General Strategy

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## For each major background type

- Construct empirical transformations of GMI multichannel brightness temperatures that optimally distinguish between background variability (“noise”) and desired precipitation (“signal”).
- Train Bayesian algorithm with DPR-derived surface rain rates matched with transformed GMI brightness temperatures.

# Channel Transformation: Conceptual Origins

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Weinman and Guetter (1977) proposed a linear transformation of dual-polarization 19 GHz ESMR brightness temperatures:

applied to the  $285 \text{ K} > I_t > 280 \text{ K}$  measurements. Scan line offsets were eliminated by a statistical analysis of the radiances which appears in each scan line; this reduced the streaks which are evident in Fig. 2 of Savage and Weinman. It was found that contrast between water and land surfaces could be eliminated by the transformation

$$\tilde{I}_t = I_t - 1.5(I_r - I_t + 2.5^\circ). \quad (17)$$

subject to the constraint that  $I_t > I_r$ . This empirical

# Conceptual Origins (cont.)

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Spencer (1986) and Spencer et al. (1989) introduced notion of a dual-polarization “pure emission line” and “polarization corrected temperature” (PCT).

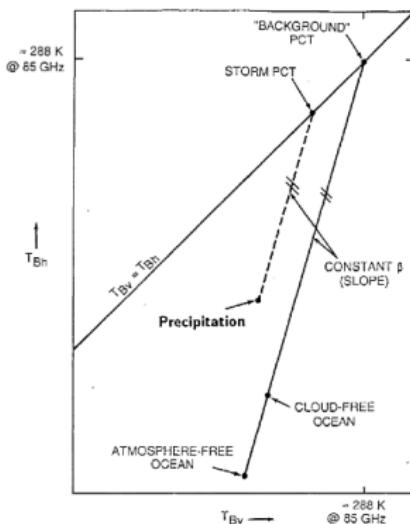


FIG. 5. Conceptual diagram of the relationships between the vertically and horizontally polarized brightness temperatures of the ocean without an overlying atmosphere, with an overlying atmosphere, a hypothetical precipitation observation, the resulting polarization corrected temperature (PCT) of the storm, and the ocean background PCT. See text for explanations of the PCT.

# A modern approach

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Petty (2013) described an objective multichannel generalization of the early ideas of Weinman and Guetter (1977) and Spencer et al. (1989).

- Observed background brightness temperature covariance defines modes of TB variability that must be rejected.
- 1st-stage linear transformation ‘spherizes’ this background noise → unit variance, uncorrelated
- 2nd-stage linear transformation isolates most of the usable precipitation signature into 1–3 “pseudochannels.”
- Combined transformation reduces 9-dimensional observation vector to a 3-dimensional vector that optimally isolates precipitation from background variability, with well-defined noise characteristics.

# Demonstration using idealized data

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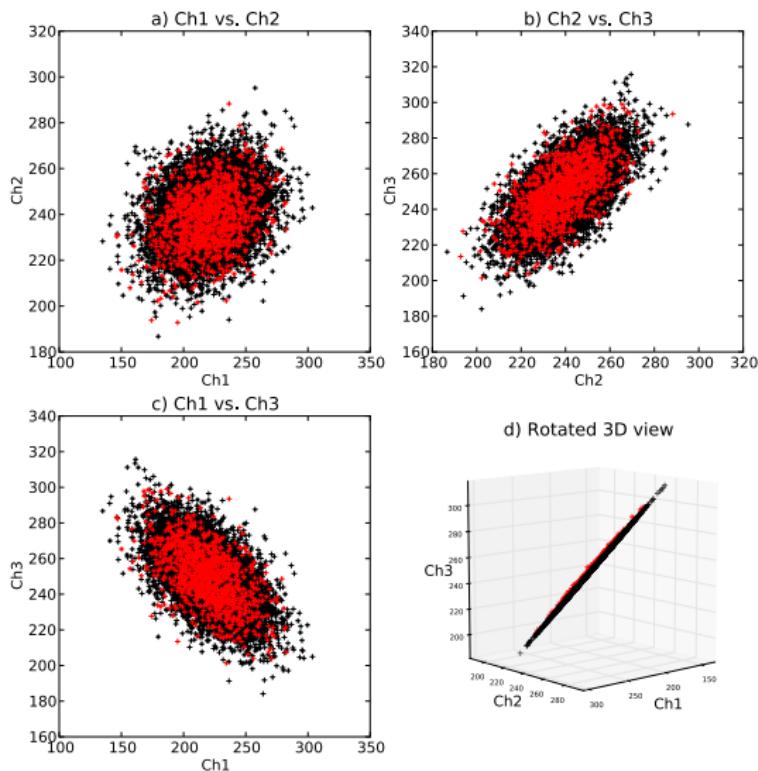
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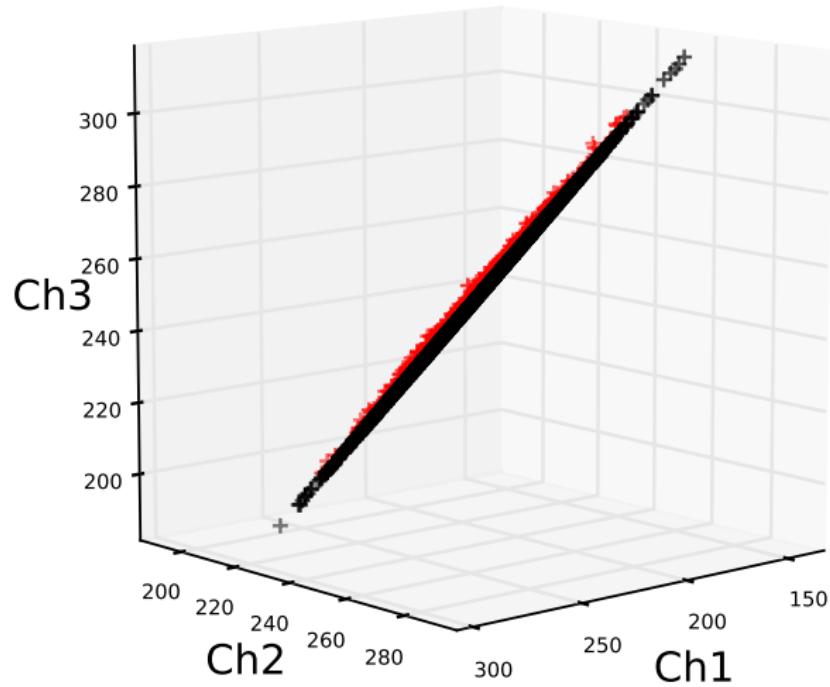
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## d) Rotated 3D view



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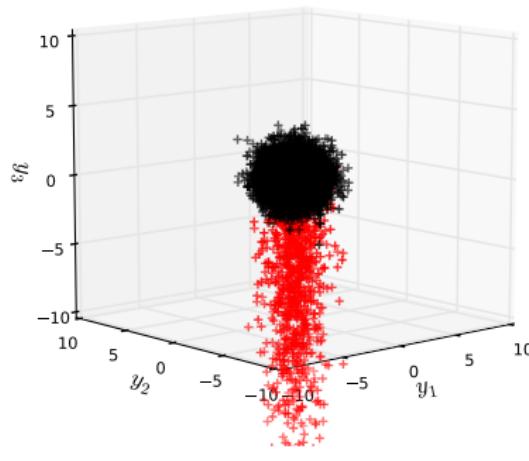
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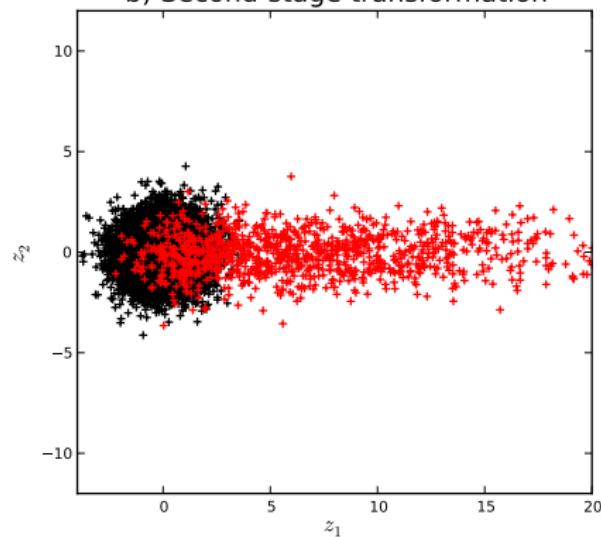
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a) First-stage transformation



b) Second-stage transformation



# Application

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Like real channels, pseudochannels can be used in any kind of empirical or physical retrieval framework.

We are pursuing two distinct paths:

**1 Adaptation to GPROF.**

- Transform observed TBs
- Transform database TBs
- Find matches in the usual way, but with rigorous criteria for defining matches (unit uncorrelated noise)

**2 Creation of a complete new Bayesian algorithm framework  
(Petty and Li 2013a)**

- Optimized land surface classifications.
- Greatly improved algorithm speed and database size (<100 MB).
- Posterior distributions of rain rate (unique!)

# Posterior Distributions of Rain Rate

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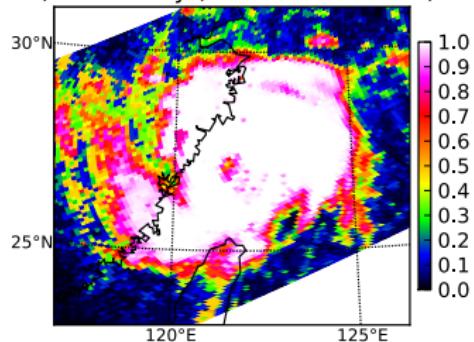
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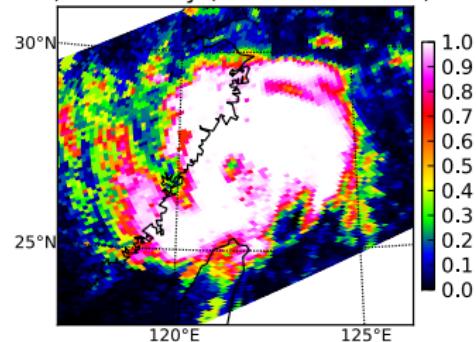
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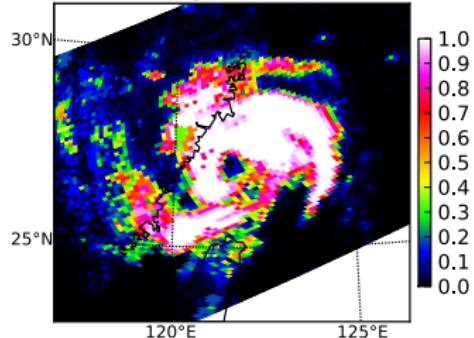
a) Probability ( $R > 0.01 \text{ mm hr}^{-1}$ )



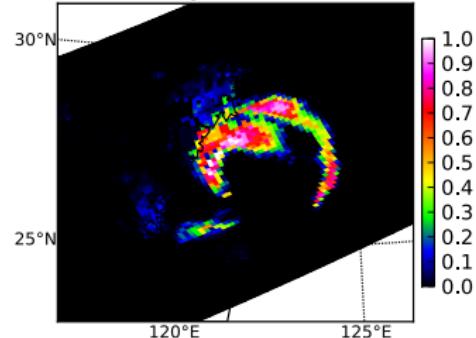
b) Probability ( $R > 0.1 \text{ mm hr}^{-1}$ )



c) Probability ( $R > 1 \text{ mm hr}^{-1}$ )



d) Probability ( $R > 10 \text{ mm hr}^{-1}$ )



# Validation

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Matchup data set was divided into two equal parts:

- 1 Training data
- 2 Independent validation data

For each surface category, two performance metrics:

- 1 Instantaneous pixel matchups
  - Emphasis on delineation *skill* as a function of validation rain rate – e.g., with what skill can the algorithm delineate rain rates in excess of  $1 \text{ mm hr}^{-1}$ ?
- 2 Gridded annual totals
  - Mean ratio
  - RMS difference
  - Correlation coefficient

# TMI Results Over Ocean (Annual 1°)

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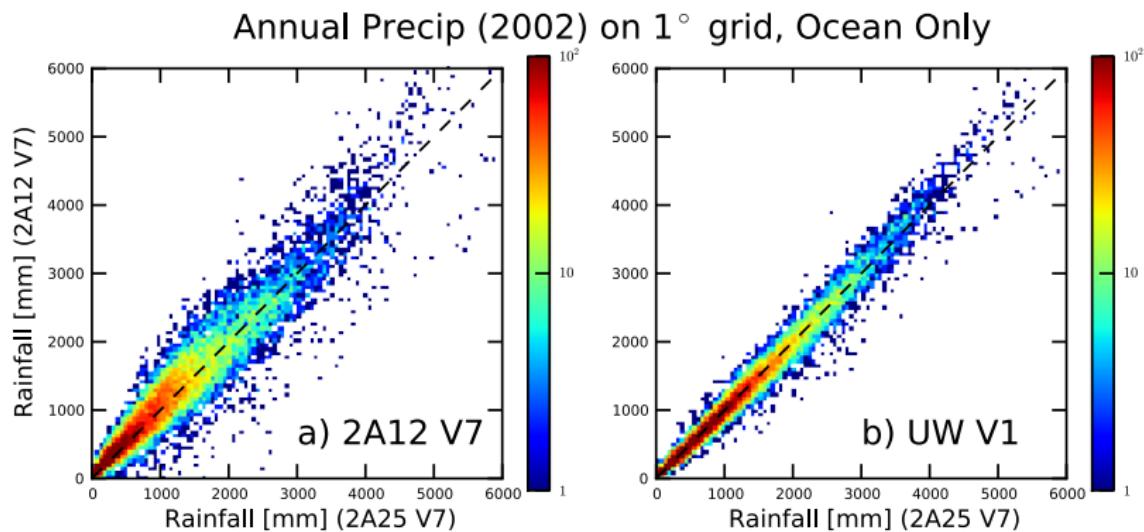
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From Petty and Li (2013b)



# TMI Results Over Ocean (Annual 1°)

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Table : Validation statistics using coincident 2A25 as “truth”

	2A12 v7	UW v1
Mean ratio	1.04	1.00
RMS error [mm]	260	129
Corr. coeff.	0.96	0.99

# TMI Results Over Vegetated Land (Annual 1°)

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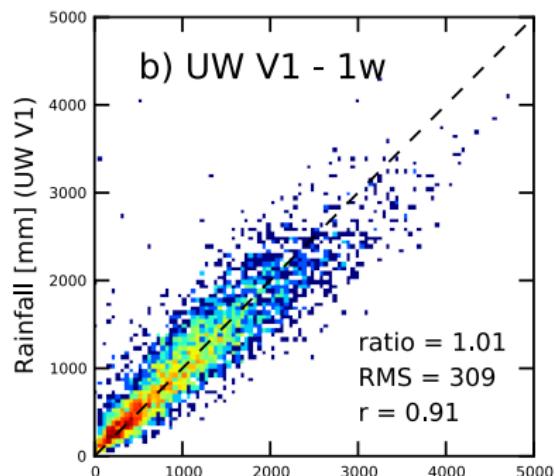
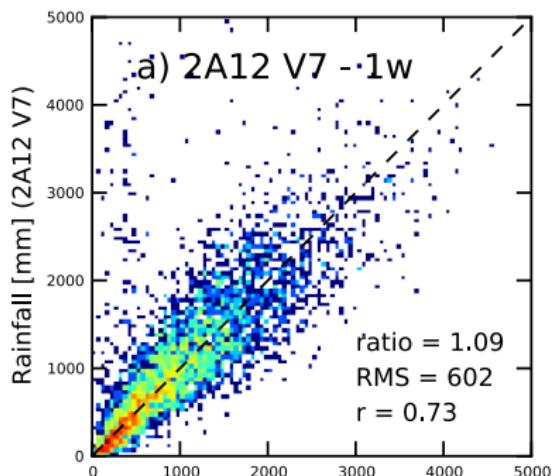
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# TMI Results over Coast (Annual 1°)

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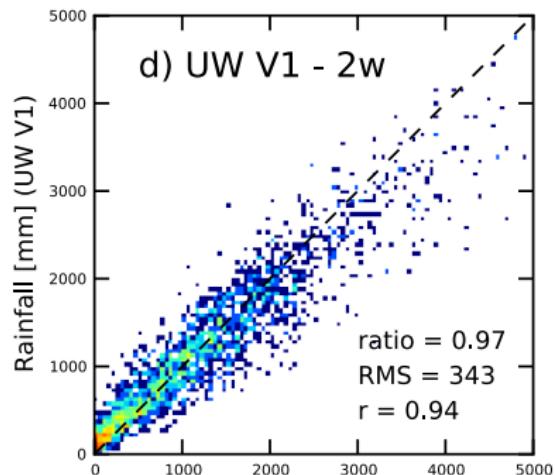
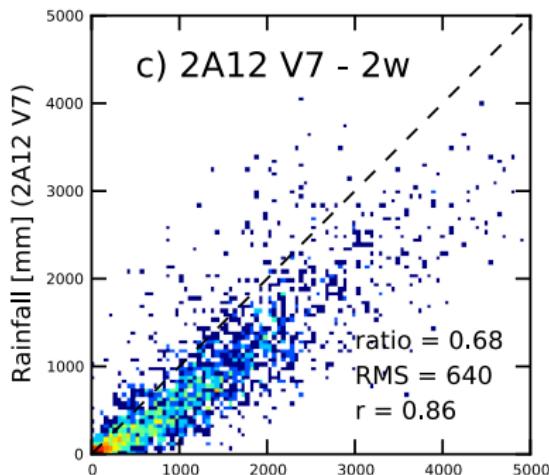
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# TMI Results over Tibetan Plateau (Annual 1°)

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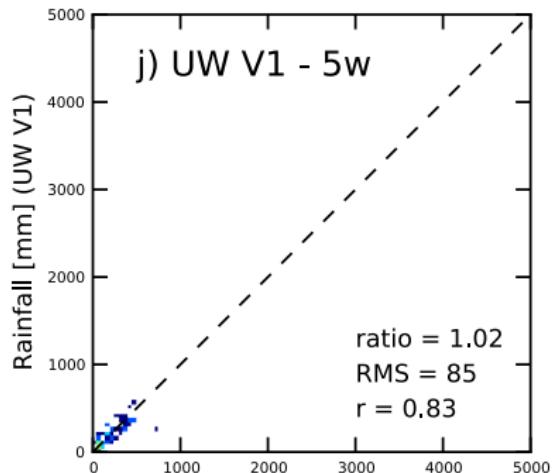
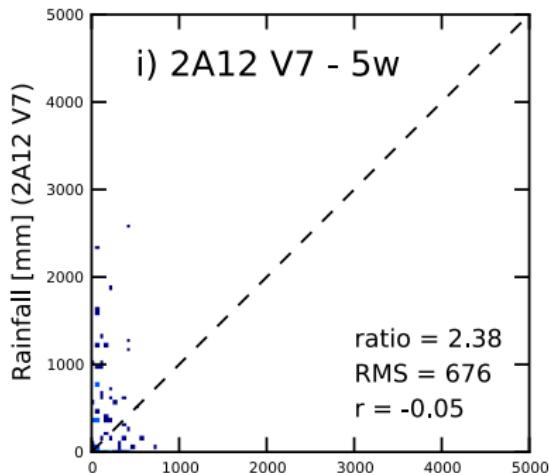
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# Adaptation to GMI

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Starting point: matchups between GMI and DPR rain rates provided by Kummerow/Petkovic (CSU).

- 12 calendar months (March 2014 – February 2015)
- $2.2 \times 10^8$  near-nadir matches
- 9 GMI channels – 10.7 to 89 GHz
- Ku-band estimated surface rain rate, averaged to GMI resolution.

# Surface Classification

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Objective method used to assign  $1^{\circ}$  grid boxes to a small number of self-similar classes based on annual means, covariances of non-precipitating 9-channel TBs:

- We avoid use of monthly or seasonal maps (time is not a relevant geophysical variable).
- Classification depends on  $T_{\text{skin}}$ 
  - 1 Ocean ( $T_{\text{skin}} > 274 \text{ K}$  ; no ice)
  - 2 Ocean ( $268 < T_{\text{skin}} < 274$  ; variable sea-ice)
  - 3 Ocean ( $T_{\text{skin}} < 268$  ; mostly sea ice)
  - 4 Coast (mixture of land and water in one grid box)
  - 5 Land 1 (no snow or ice)
  - 6 Land 2 (“)
  - 7 Land 3 (“)
  - 8 Land 1 (possible snow or ice)
  - 9 Land 2 (“)
  - 10 Land 3 (“)

# Warm Land + Coast

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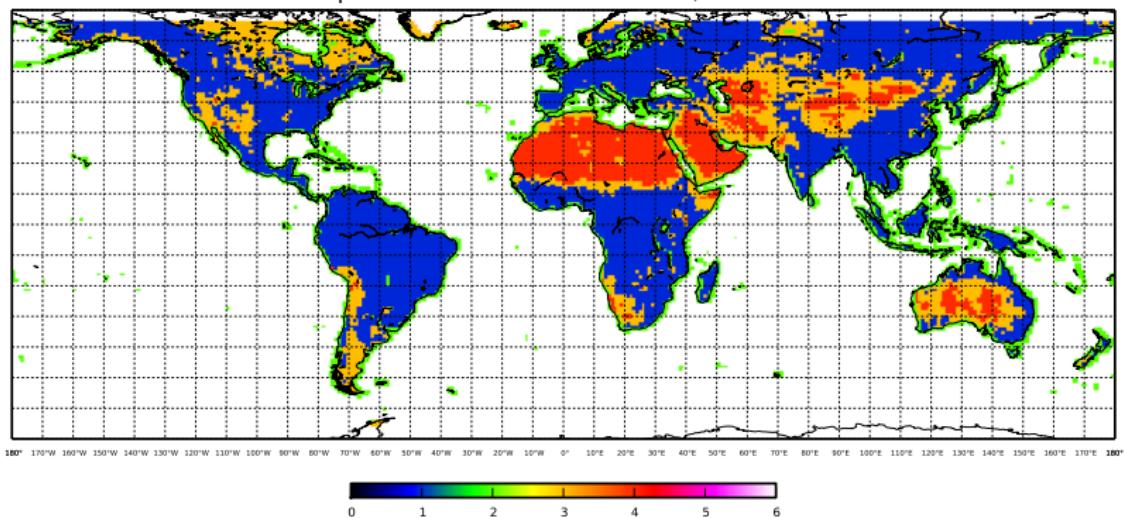
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Empirical Surface Classes - Land,  $T > 275$  K



# Cold Land (snow or ice possible)

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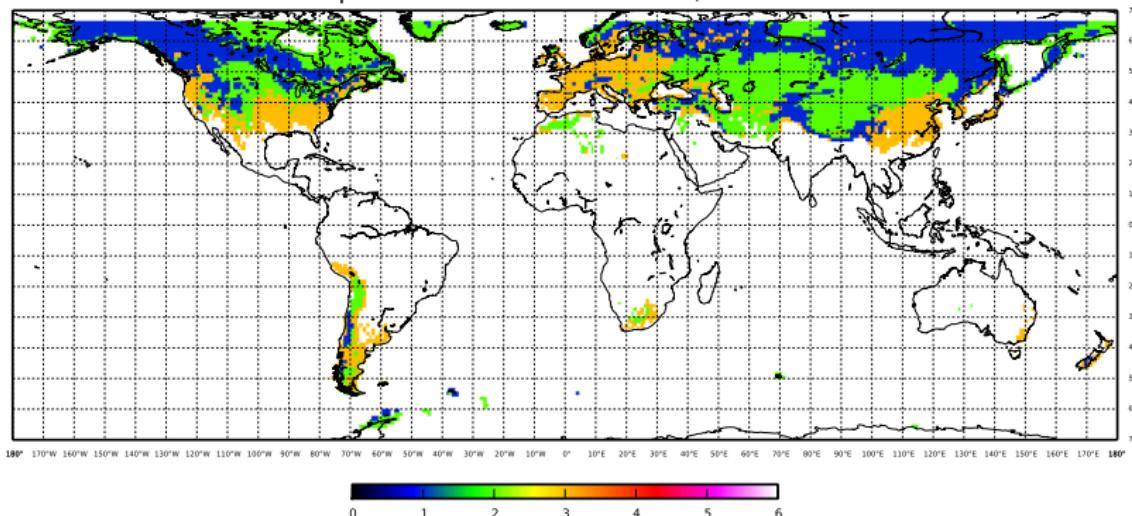
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Empirical Surface Classes - Land,  $T < 275$  K



# Instantaneous Skill - Ocean (ice-free)

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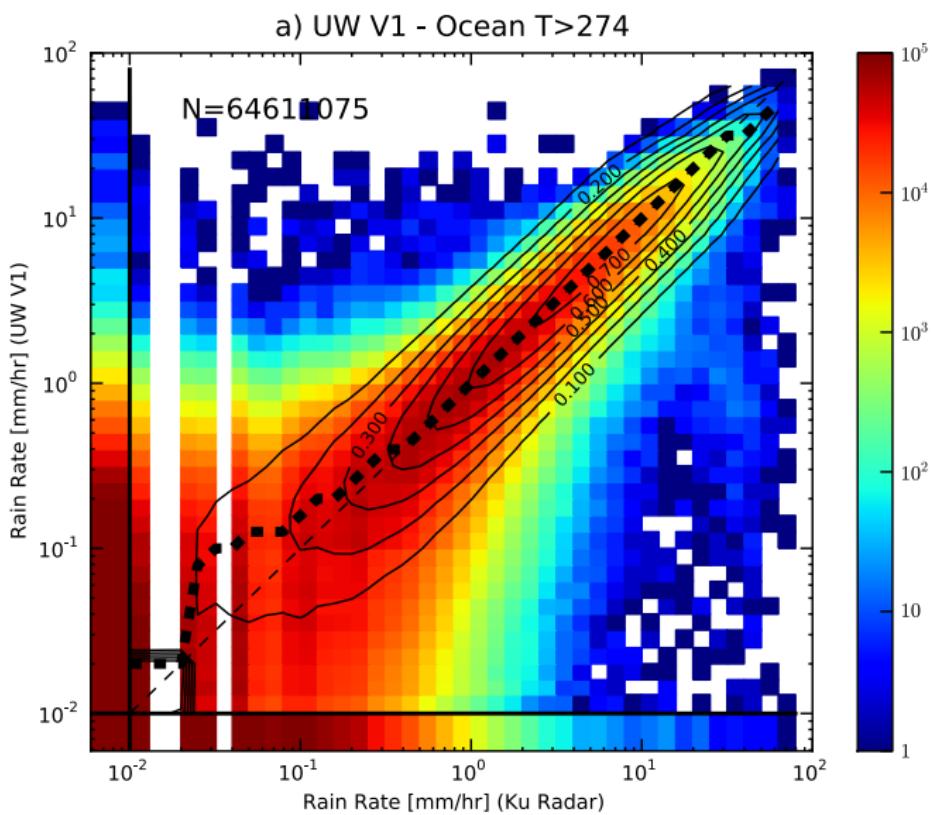
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# Instantaneous Skill - Ocean (transition)

Surface-insensitive retrievals

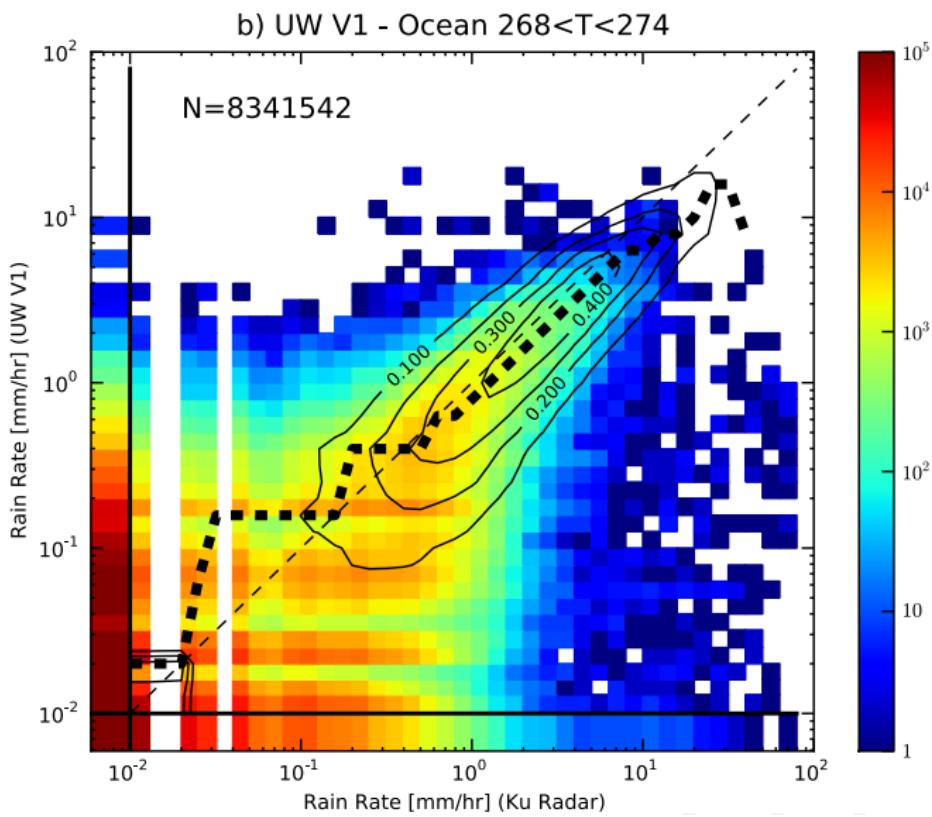
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# Instantaneous Skill - Ocean (sea ice)

Surface-insensitive retrievals

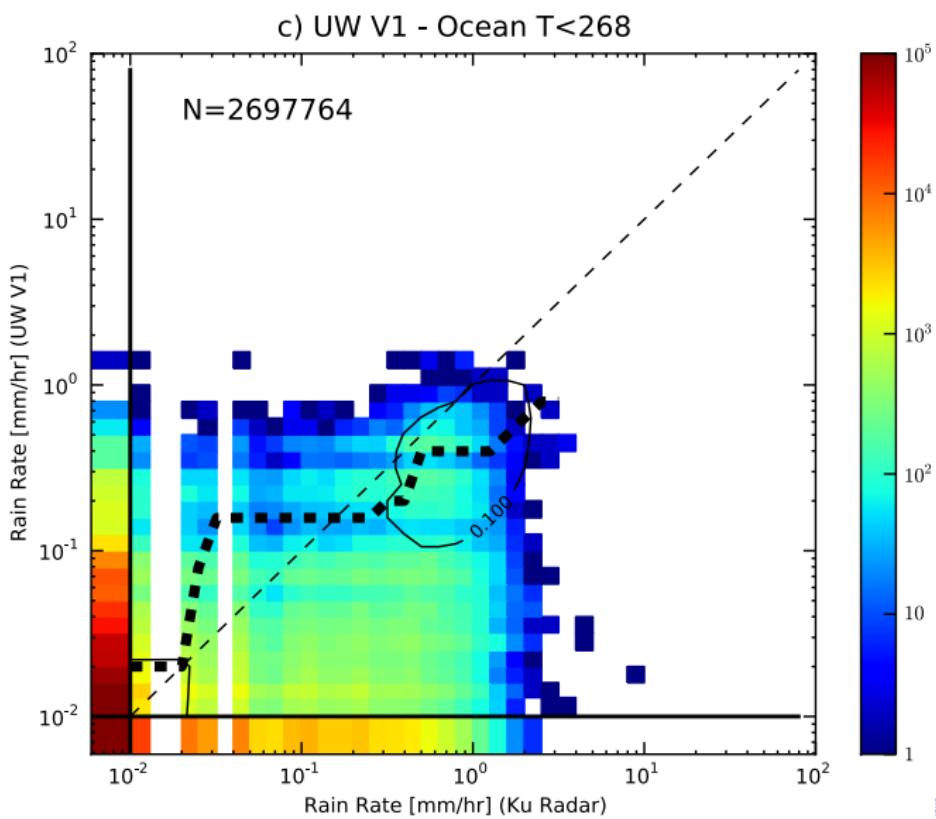
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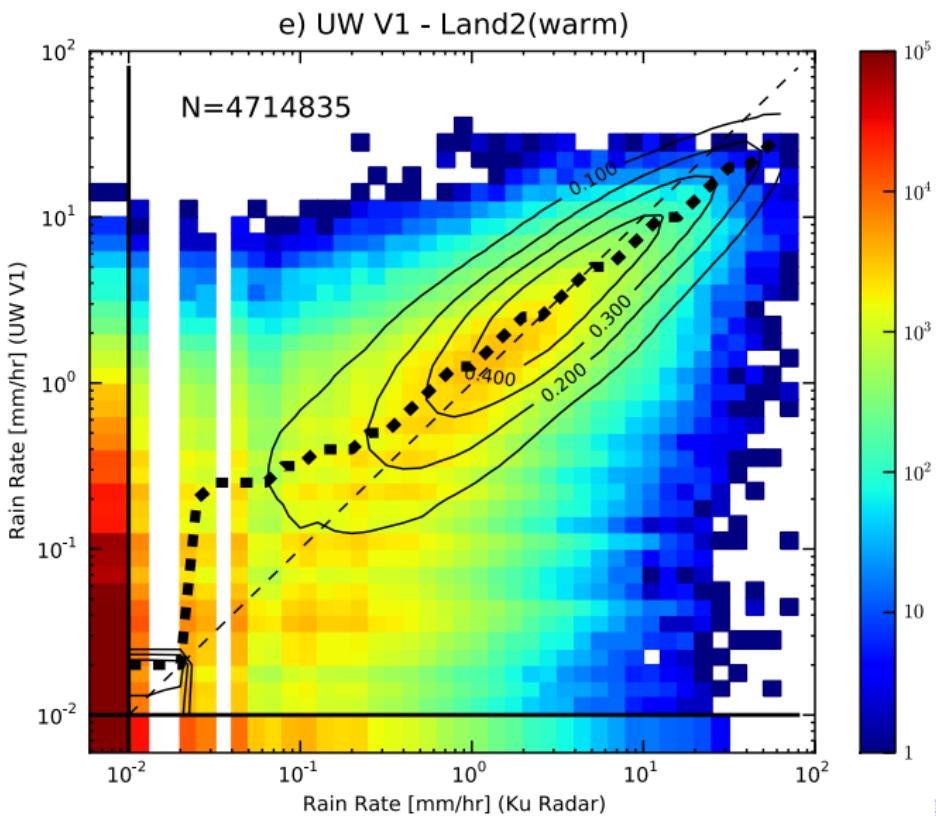
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# Instantaneous Skill - Coast

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# Instantaneous Skill - Vegetated Land

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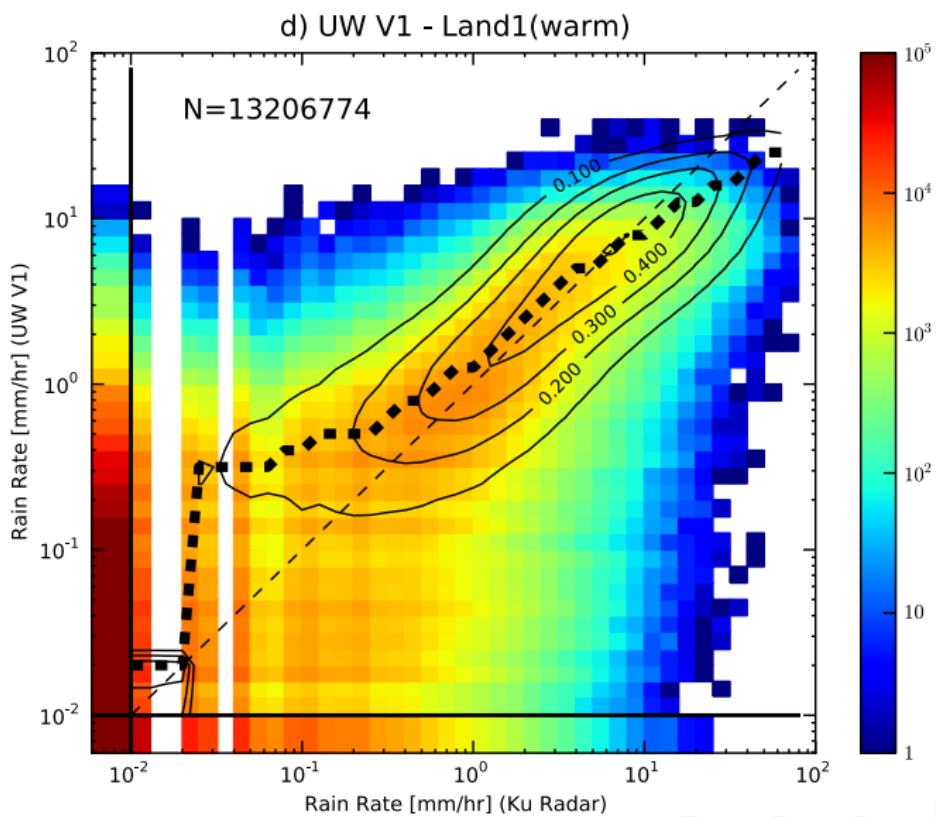
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# Instantaneous Skill - Semi-Arid

Surface-insensitive retrievals

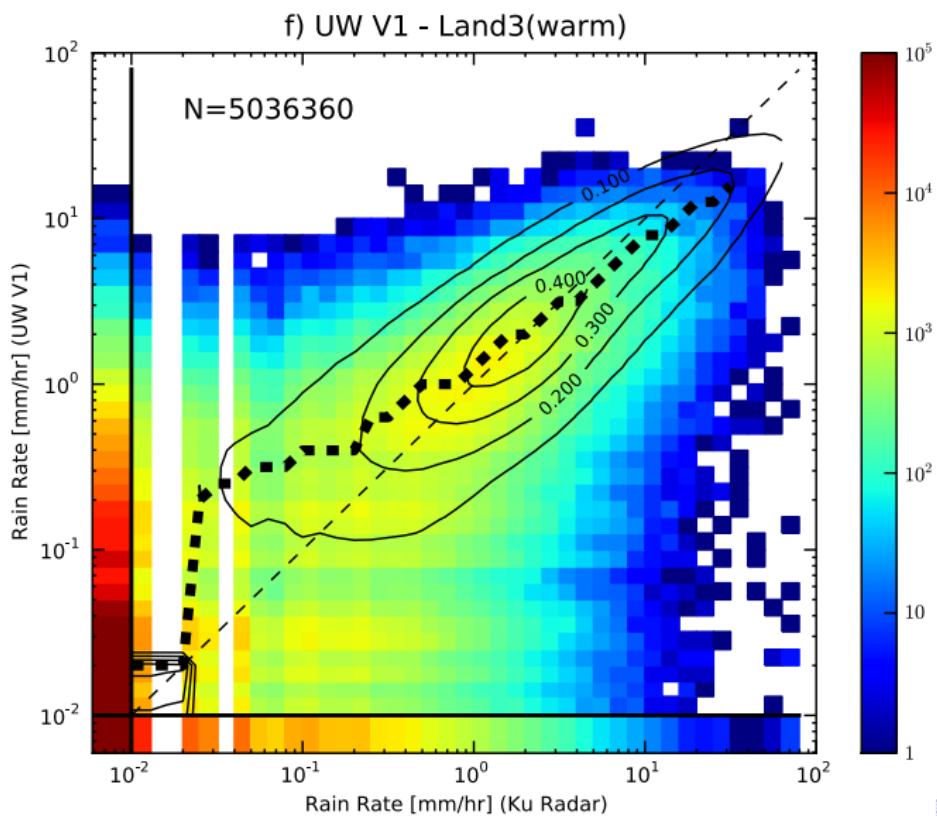
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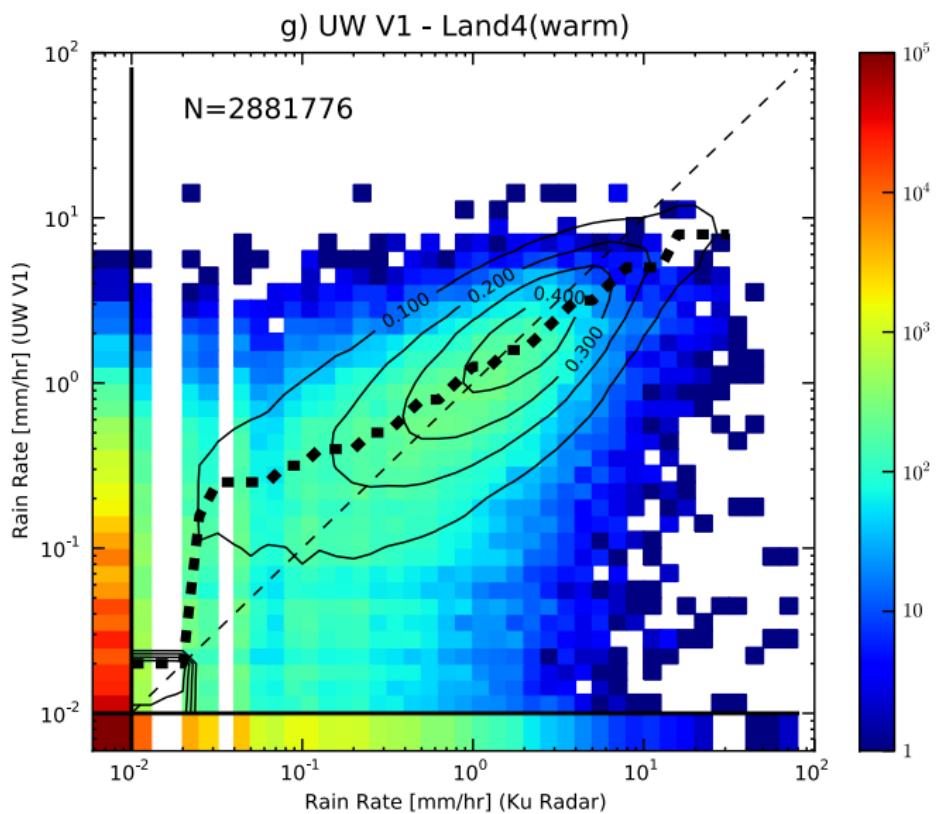
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## Instantaneous Skill - Desert

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## Adaptation to GMI



# Instantaneous Skill - Land 1 (cold)

Surface-insensitive retrievals

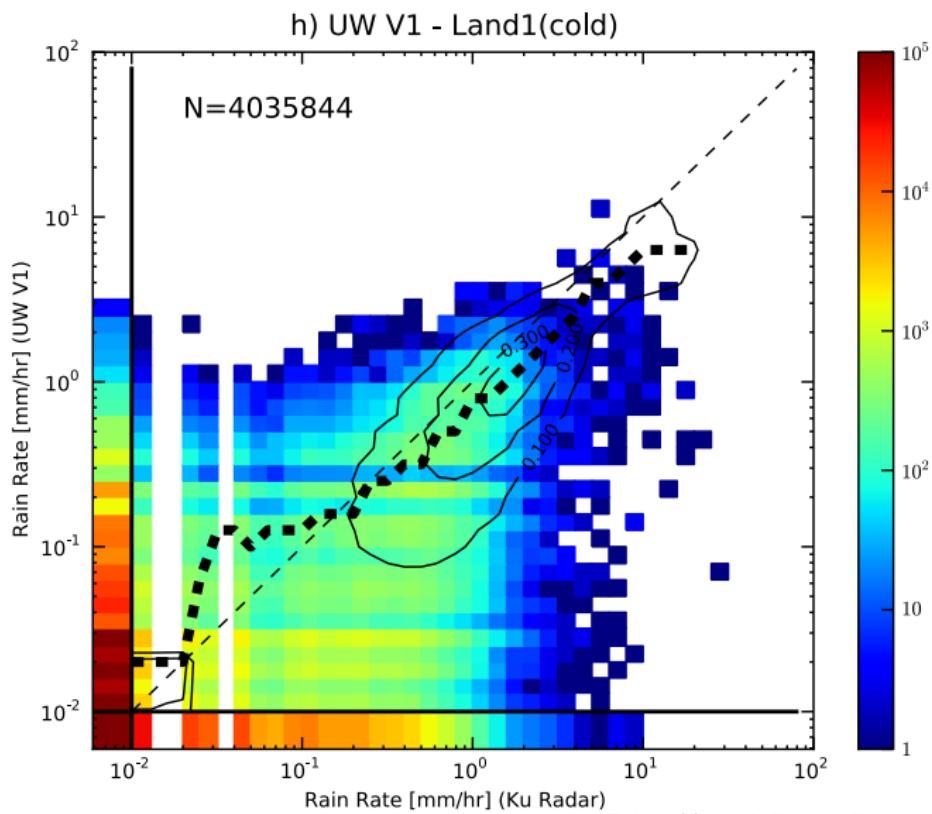
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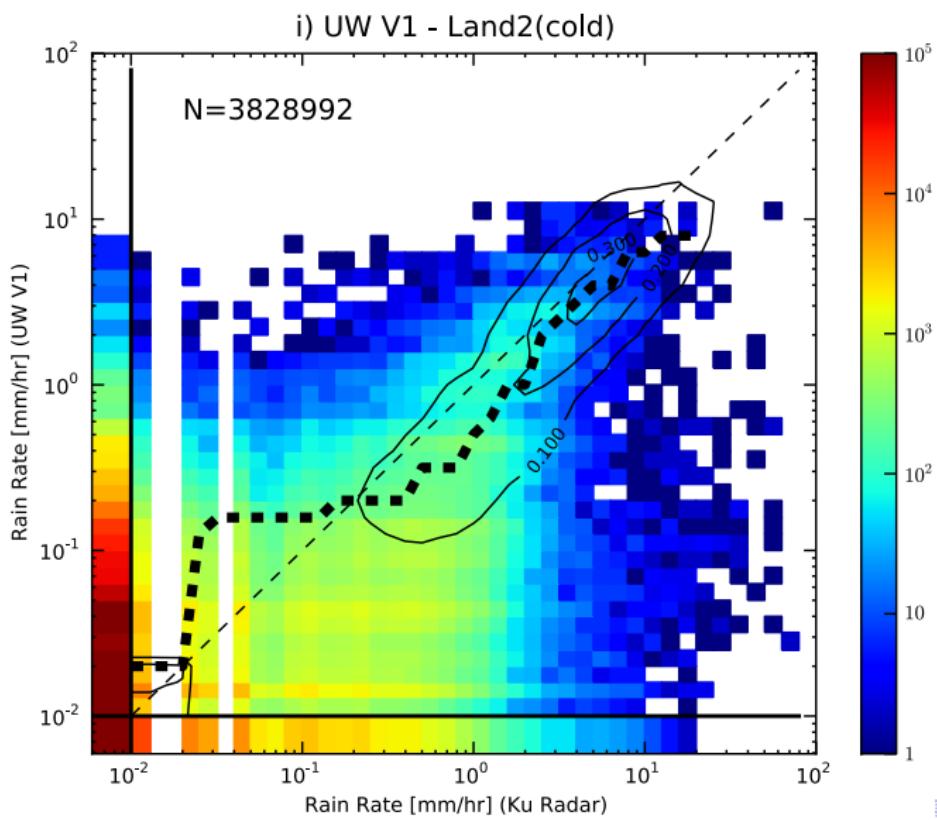
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## Instantaneous Skill - Land 2 (cold)

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## Adaptation to GMI



# Instantaneous Skill - Land 3 (cold)

Surface-insensitive retrievals

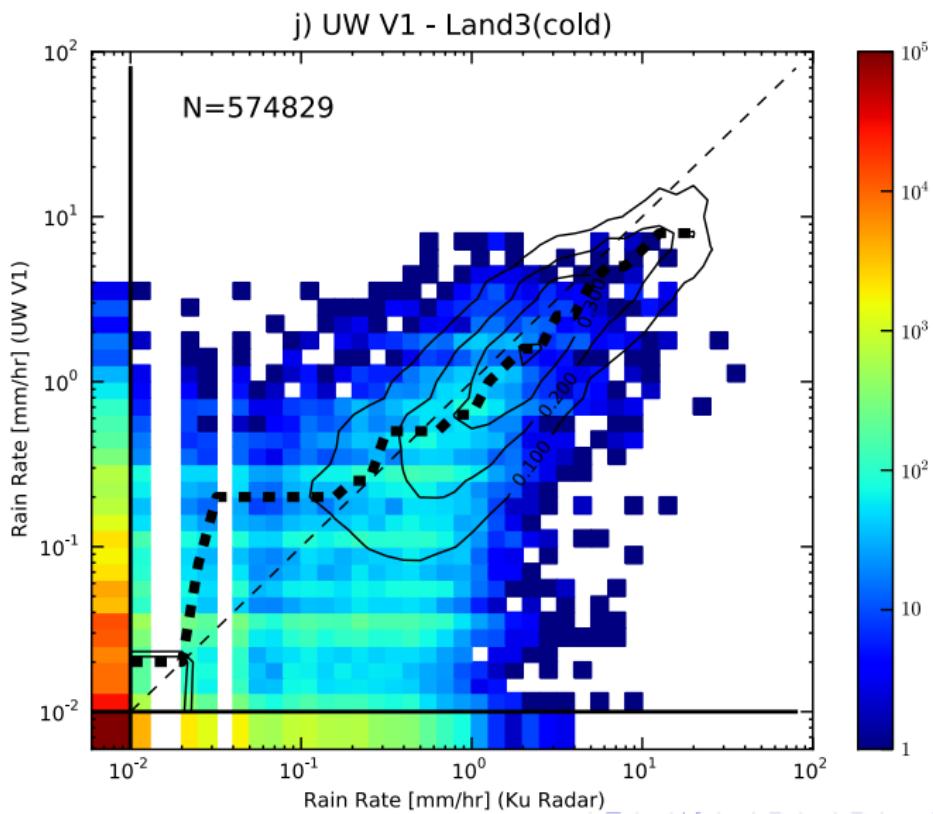
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# Annual Total [mm] - Ocean (ice-free)

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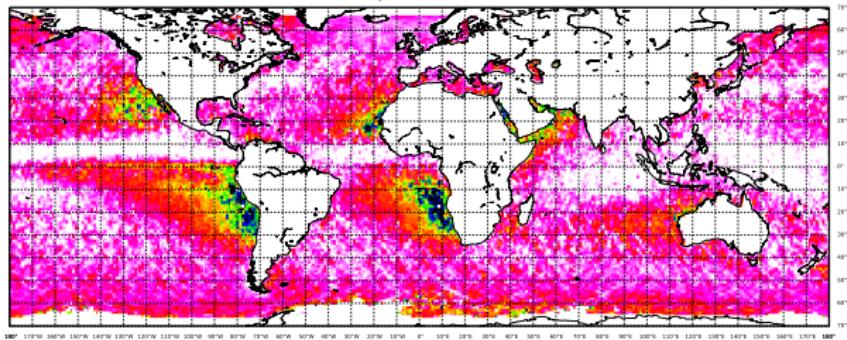
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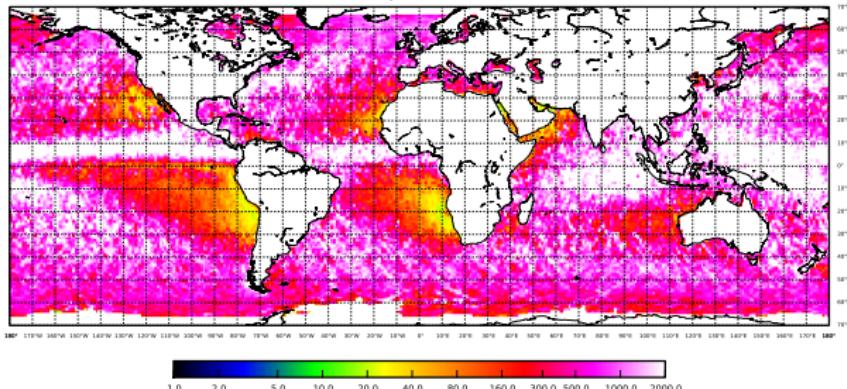
Adaptation to  
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a) Ku Radar



b) UW V1



# Annual Total [mm] - Ocean (transition)

Surface-  
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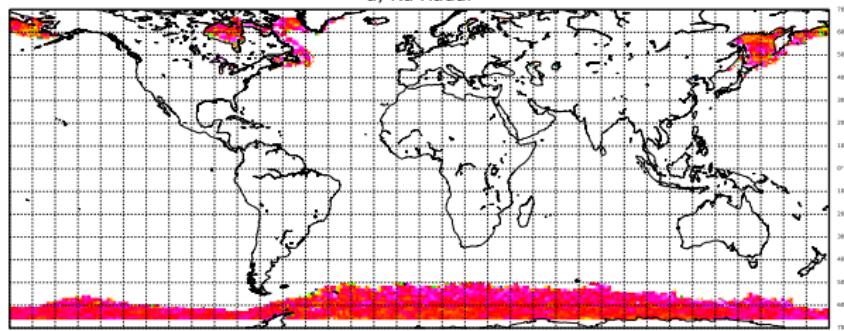
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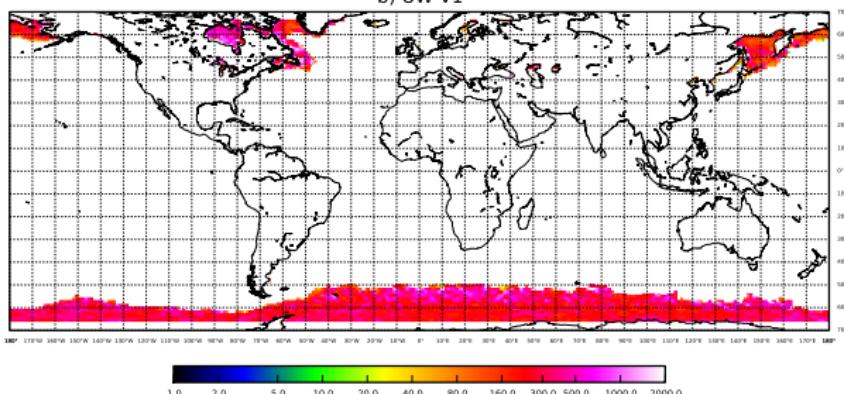
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b) UW V1



# Annual Total [mm] - Ocean (sea ice)

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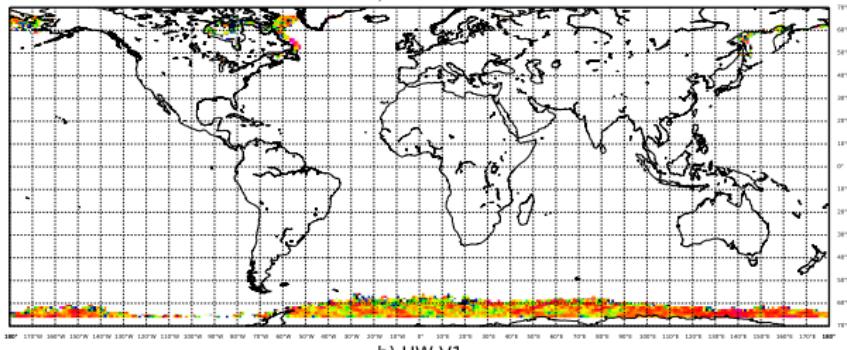
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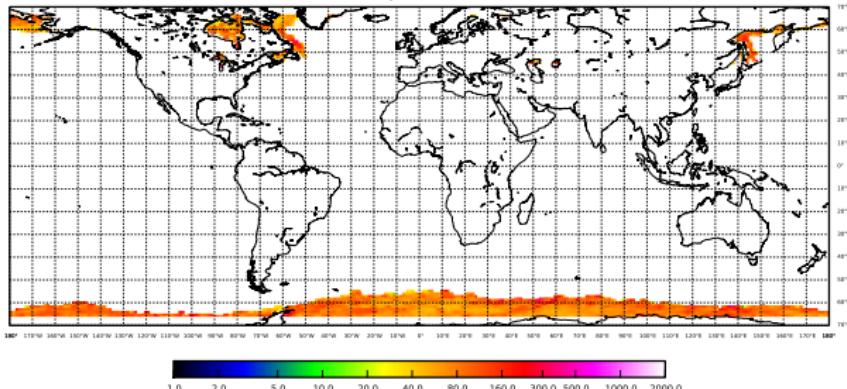
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a) Ku Radar



b) UW V1



# Annual Total [mm] - Coast

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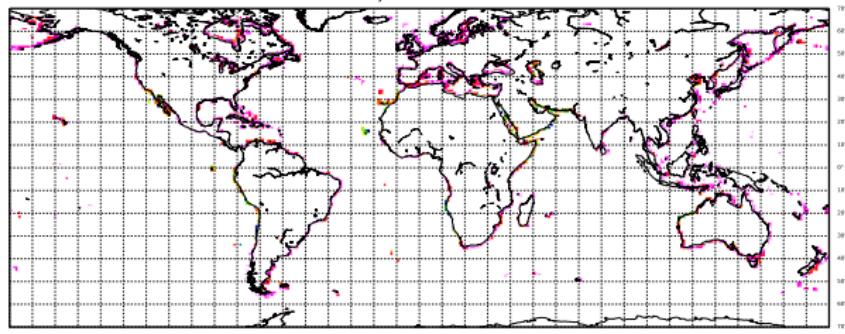
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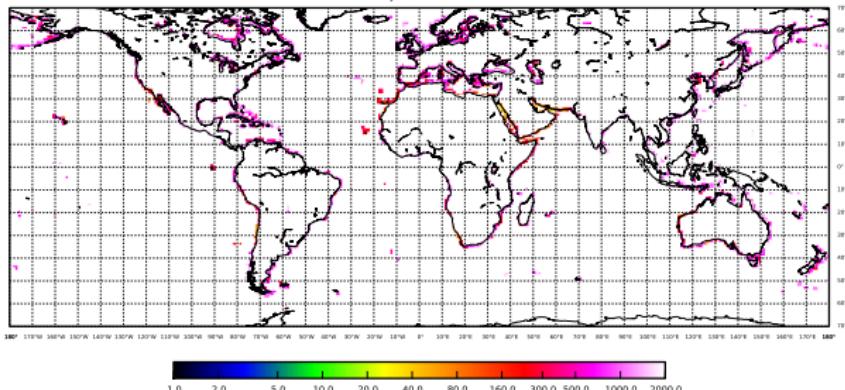
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a) Ku Radar



b) UW V1



# Annual Total [mm] - Vegetated Land

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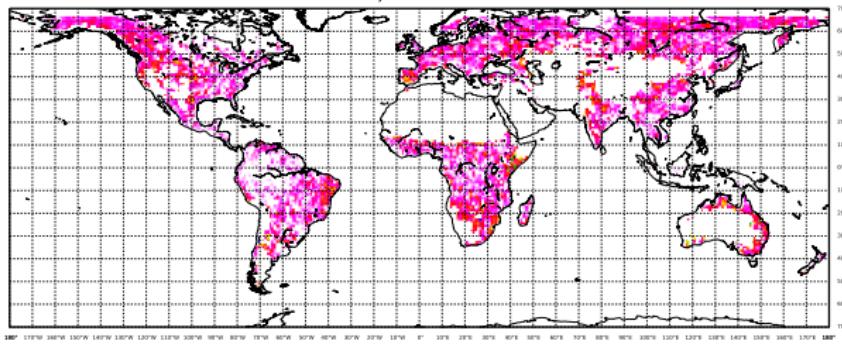
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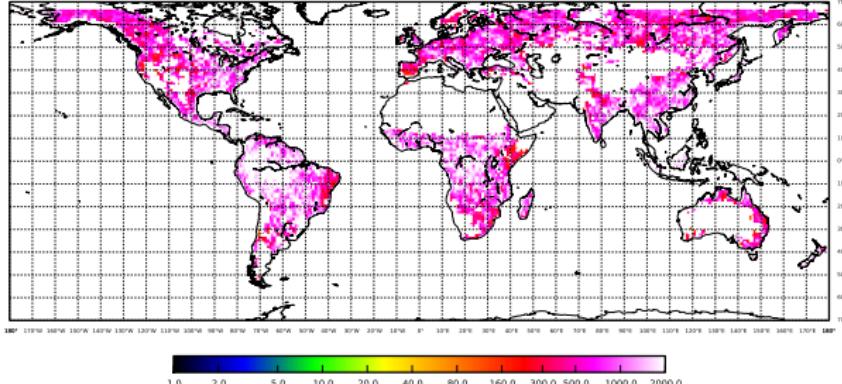
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a) Ku Radar



b) UW V1



# Annual Total [mm] - Semi-Arid

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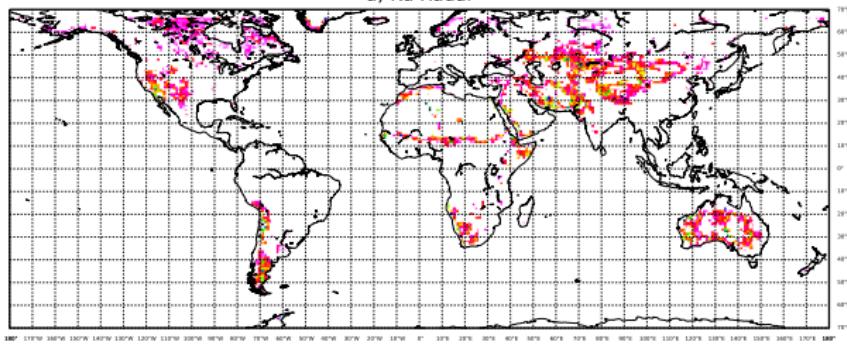
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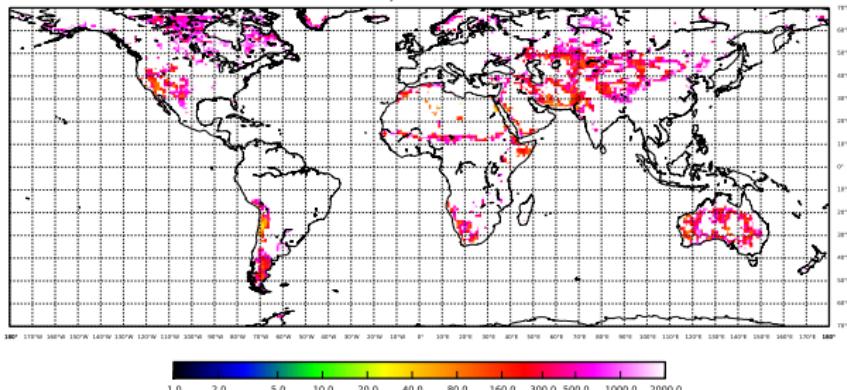
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a) Ku Radar



b) UW V1



# Annual Total [mm] - Desert

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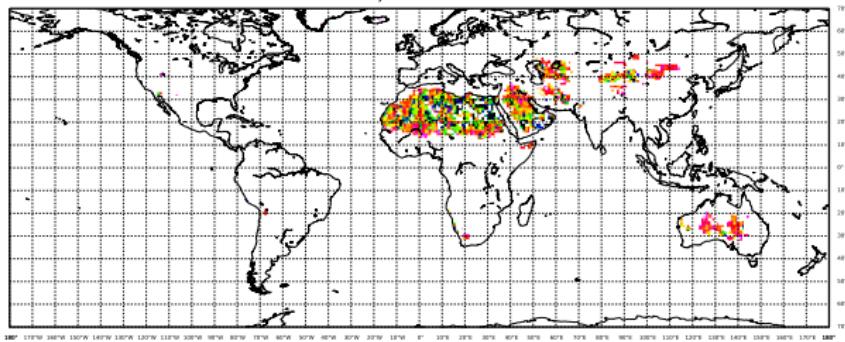
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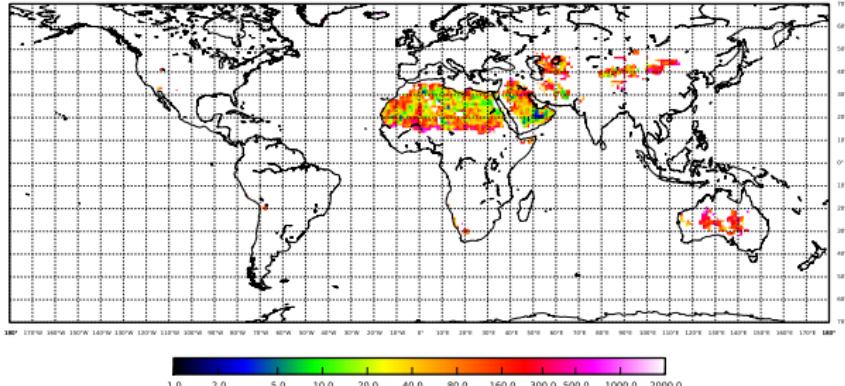
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a) Ku Radar



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# Annual Total [mm] - Land 1 (cold)

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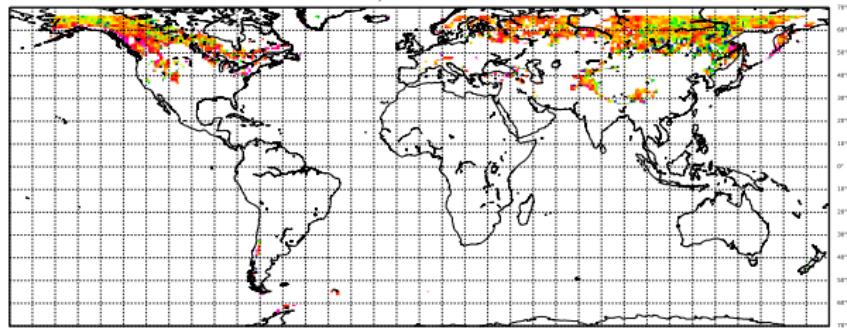
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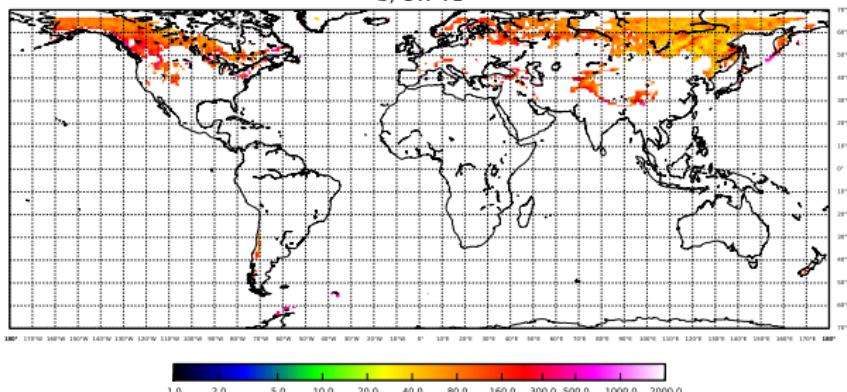
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# Annual Total [mm] - Land 2 (cold)

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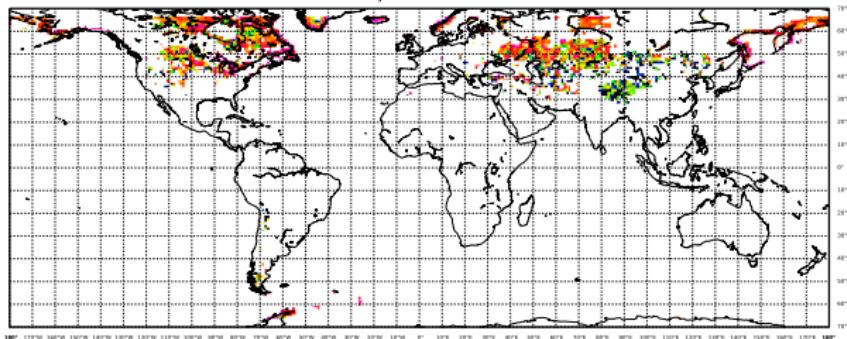
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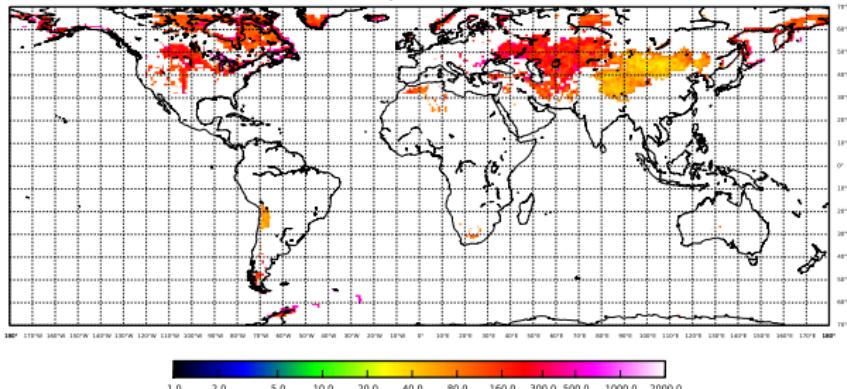
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# Annual Total [mm] - Land 3 (cold)

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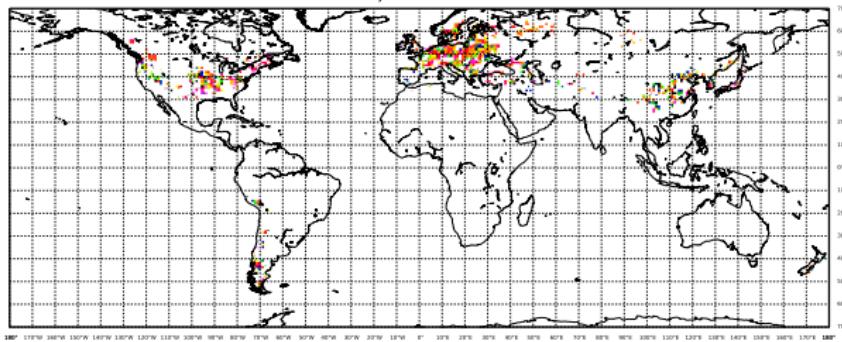
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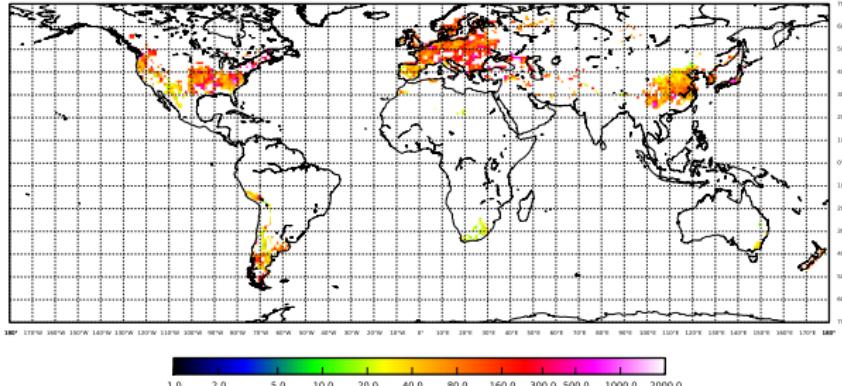
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# Annual Total [mm] - All Surface Types

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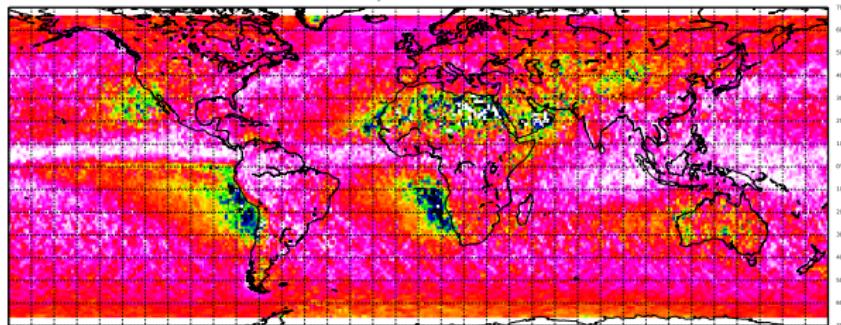
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TMI

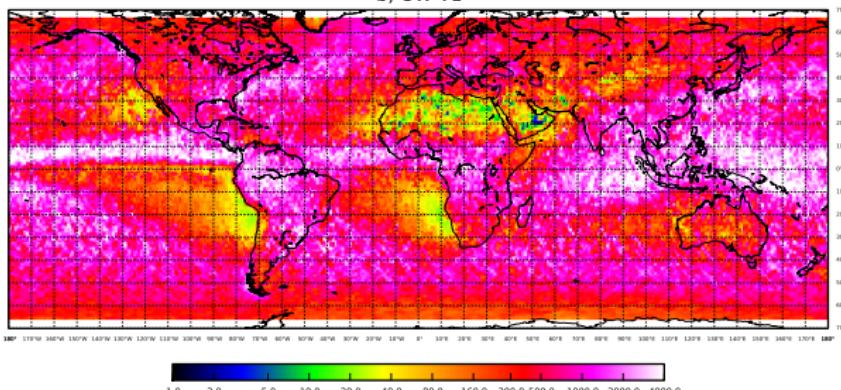
Adaptation to  
GMI

Conclusions

a) Ku Radar



b) UW V1



# Annual Total [mm] - All Surface Types

Surface-insensitive retrievals

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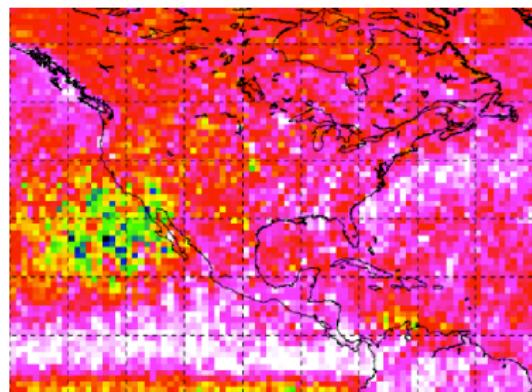
Overview

Results for  
TMI

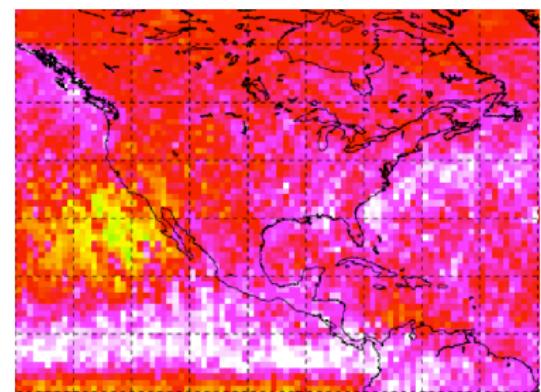
Adaptation to  
GMI

Conclusions

Ku band radar



UW v1



# Annual Total [mm] - Ocean (ice-free)

Surface-insensitive retrievals

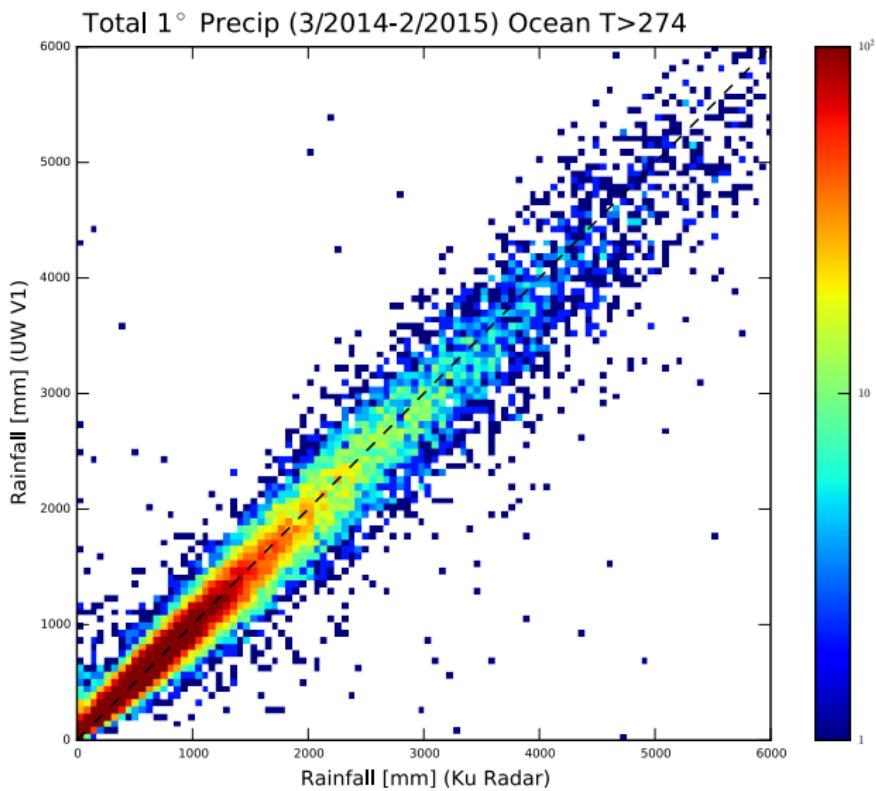
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Overview

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TMI

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GMI

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# Annual Total [mm] - Ocean (transition)

Surface-insensitive retrievals

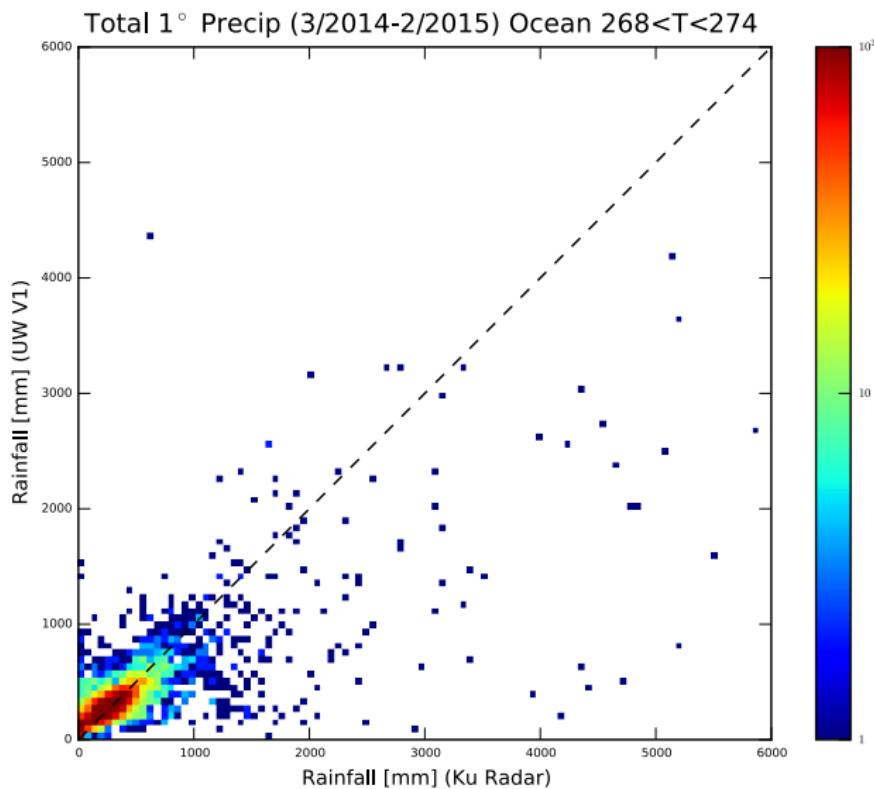
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TMI

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# Annual Total [mm] - Ocean (sea ice)

Surface-insensitive retrievals

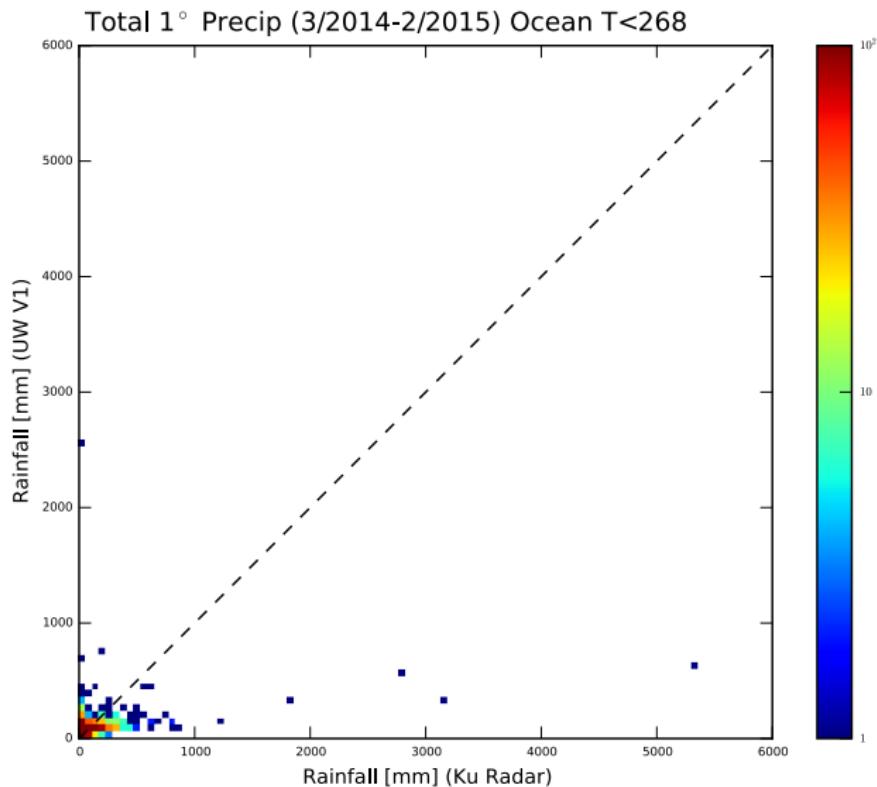
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# Annual Total [mm] - Coast

Surface-insensitive retrievals

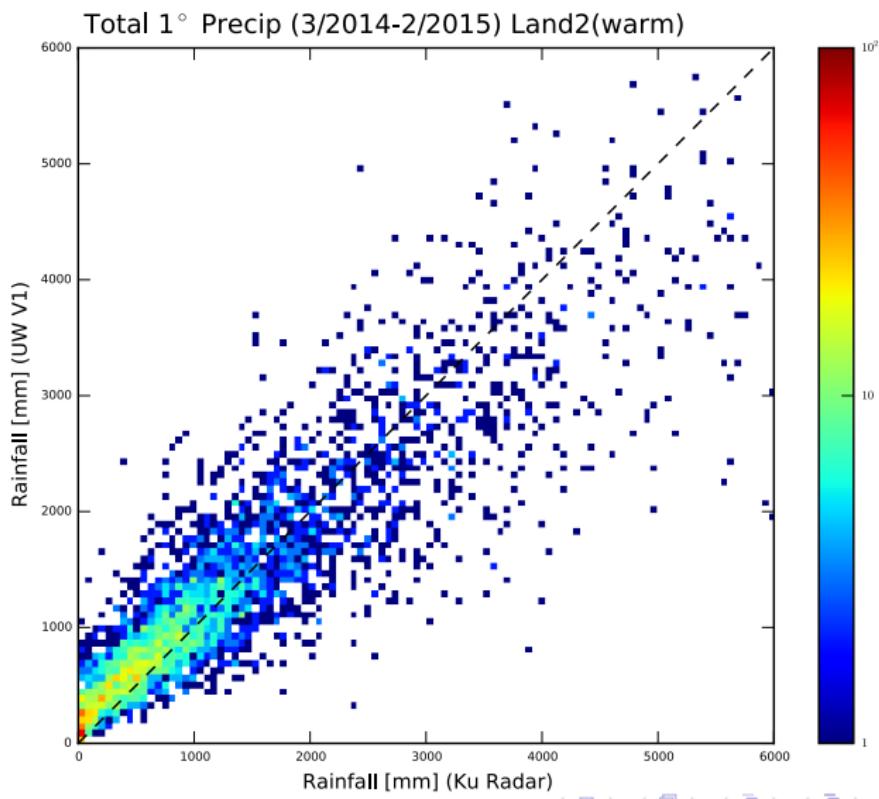
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# Annual Total [mm] - Vegetated Land

Surface-insensitive retrievals

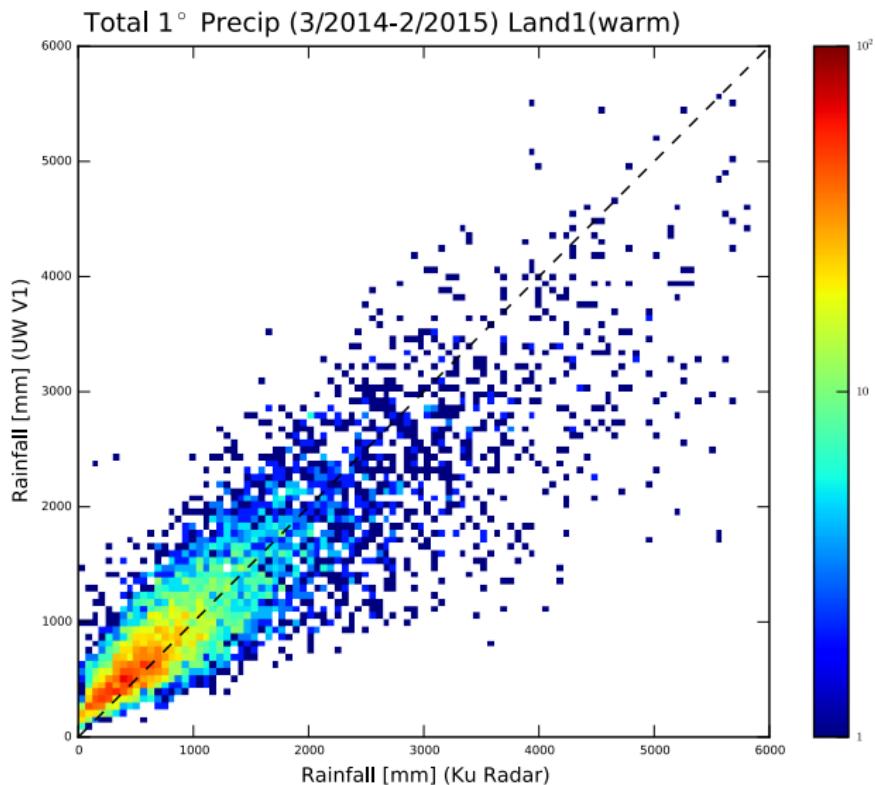
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# Annual Total [mm] - Semi-Arid

Surface-insensitive retrievals

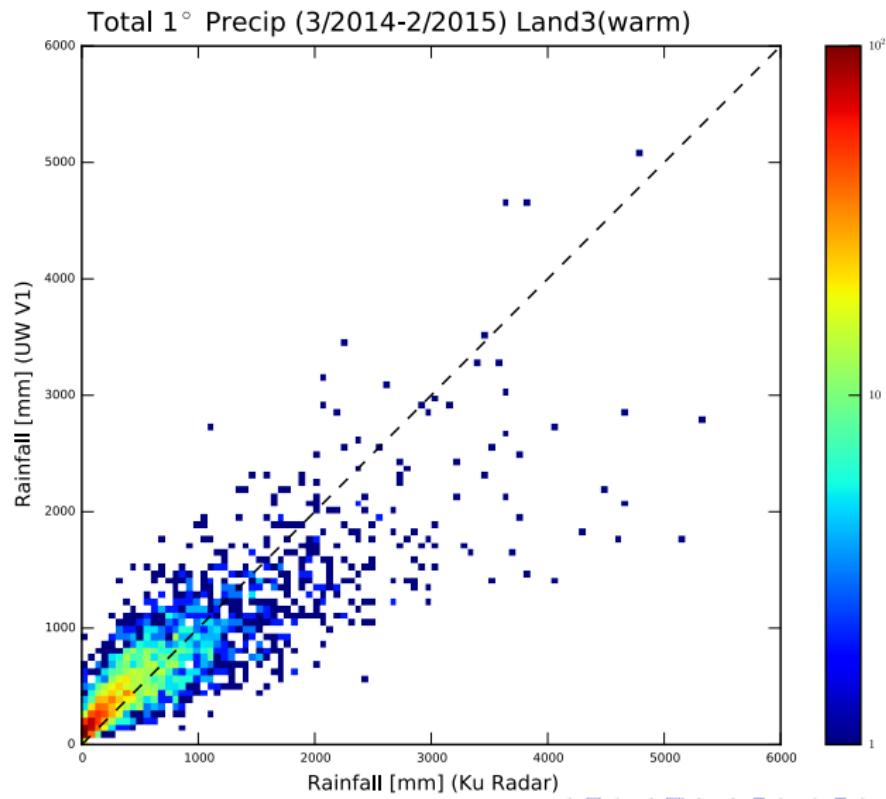
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# Annual Total [mm] - Desert

Surface-insensitive retrievals

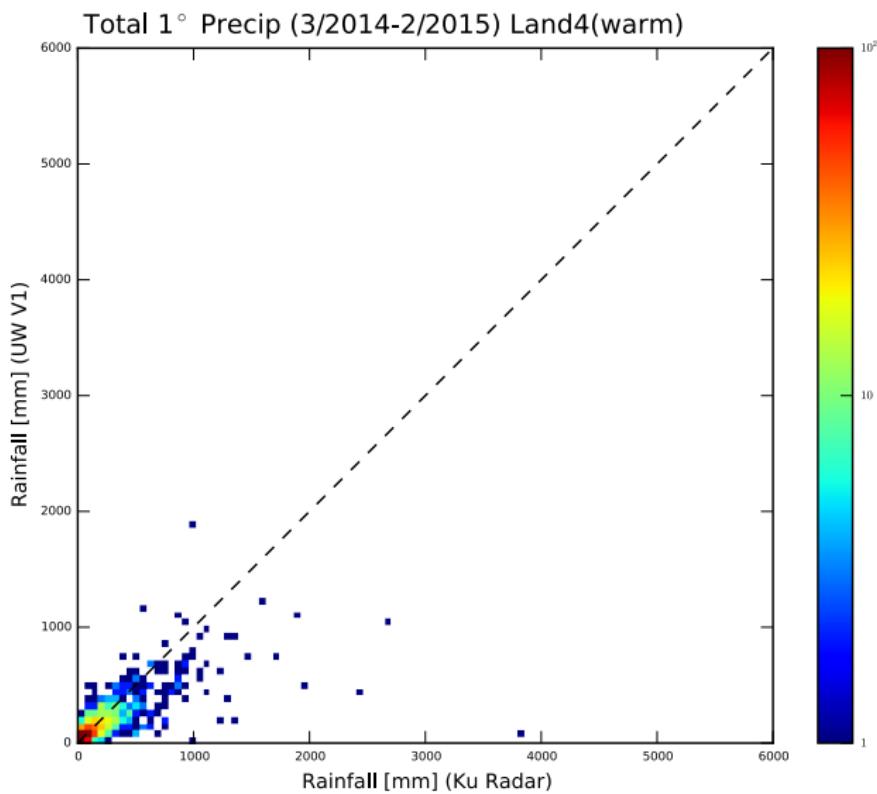
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# Annual Total [mm] - Land 1 (cold)

Surface-insensitive retrievals

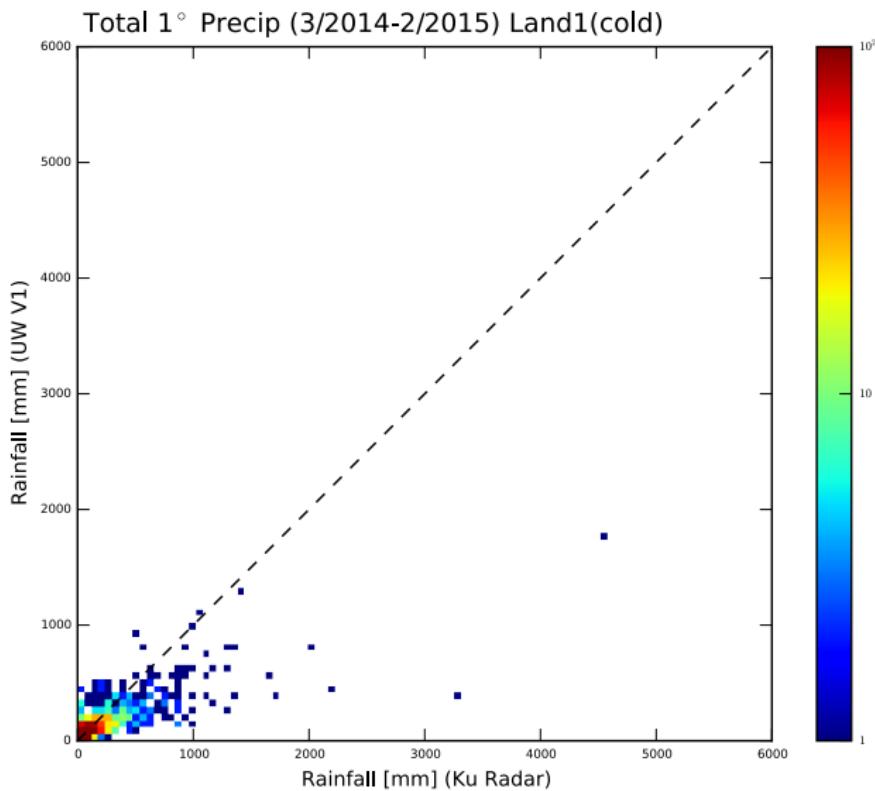
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# Annual Total [mm] - Land 2 (cold)

Surface-insensitive retrievals

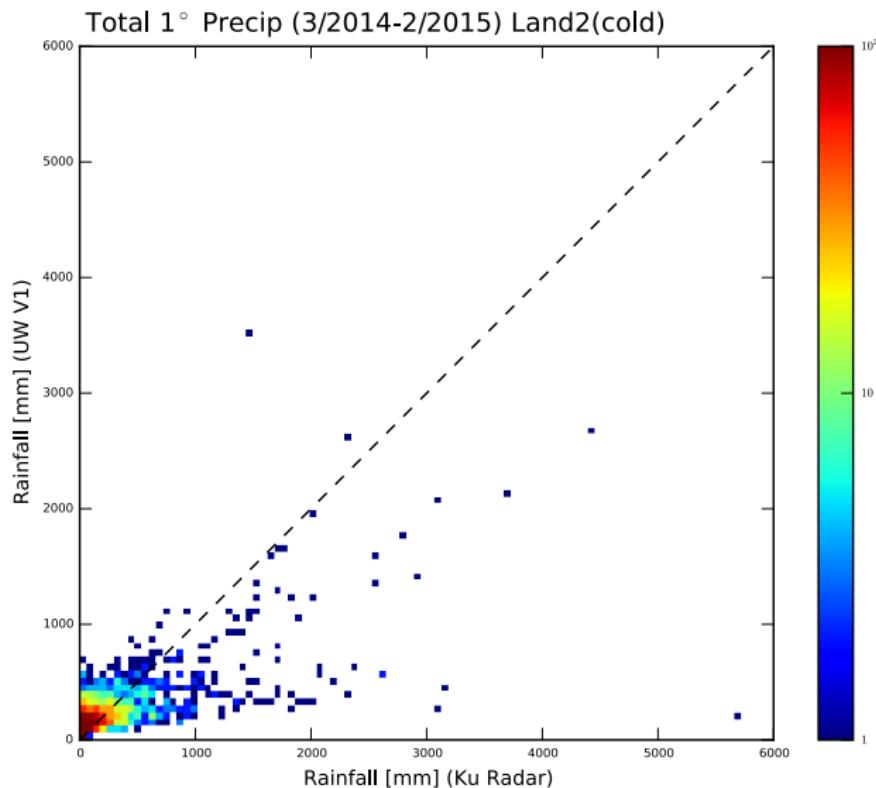
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# Annual Total [mm] - Land 3 (cold)

Surface-insensitive retrievals

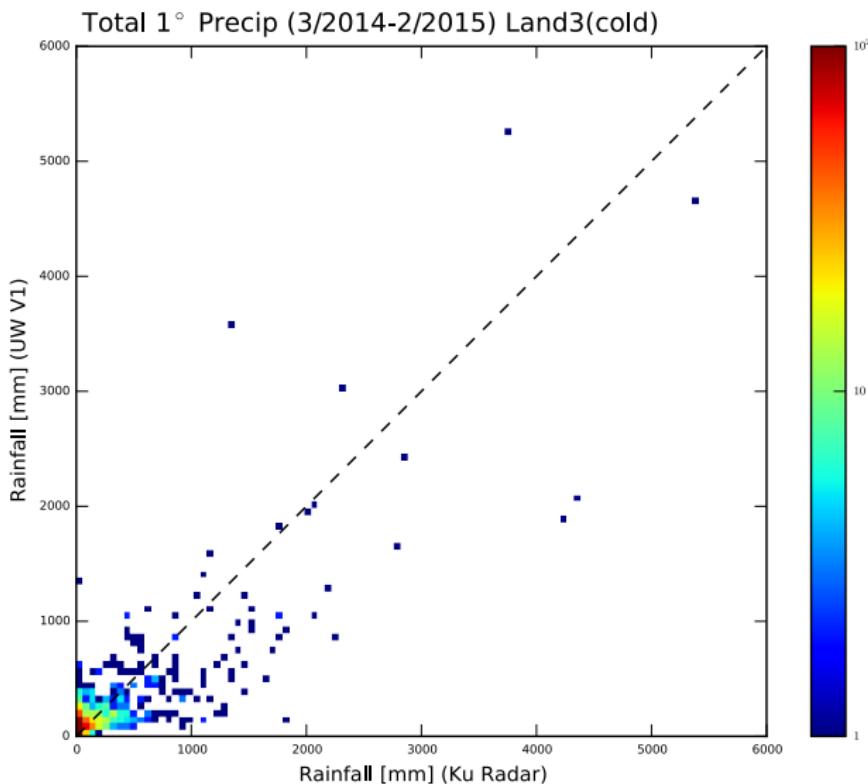
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# Conclusions

Surface-insensitive retrievals

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- Over non-frozen surfaces, pseudochannel approach works about as well for GMI as previously documented for TMI.
- As for TMI, detection of light precipitation is good, even over coastlines, deserts, and other problem surfaces.
- Retrievals over sea ice and snow-covered ground show reduced apparent skill, but no unwanted artifacts.

# Ongoing Work

Surface-insensitive retrievals

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- Adapt to GPROF.
- Expand matchup data base.
- Parameterize rain rate distribution functions.
- Over snow and ice, adapt technique to 166+ GHz channels
- Examine value of improved resolution matching.

# References

Surface-insensitive retrievals

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## Surface- insensitive retrievals

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# The End